UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED PHYSICS & ENGINEERING MATHEMATICS

NATIONAL DIPLOMA IN CHEMICAL ENGINEERING

MODULE PHY1BCT
ENGINEERING PHYSICS II

CAMPUS **DFC**

NOVEMBER EXAMINATION

DATE: 05 November 2015 **SESSION: 12:30 – 15:30**

ASSESSOR **Mr. T.G. Mathe**

INTERNAL MODERATOR **Dr. L. Reddy**

DURATION **3 HOURS** **MARKS** **140**

NUMBER OF PAGES: 9 PAGES, INCLUDING 2 ANNEXURE (DATA SHEET).

INSTRUCTIONS:

- **ANSWER ALL THE QUESTIONS.**
- **KEEP ALL SUB-QUESTIONS TOGETHER**
- **CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).**
- **START EACH QUESTION ON A NEW PAGE.**
- **NUMERICAL ANSWERS ARE TO BE EXPRESSED IN SCIENTIFIC NOTATION & CORRECT NUMBER OF SIGNIFICANT FIGURES OBSERVED.**
- **WORK WRITTEN IN PENCIL WILL NOT BE MARKED. ONLY DRAWINGS ARE TO BE DONE IN PENCIL.**

REQUIREMENTS: ONE EXAMINATION ANSWER SCRIPTS PER STUDENT

/2…

Question 1 – Hydrodynamics [35 marks]

1.1 Differentiate between a Newtonian fluid and a non-Newtonian fluid. Give ONE example of each. (4)

1.2 Water flows straight down from an open tap. The effects of air resistance and viscosity can be ignored.

1.2.1 After the water has fallen a bit below the tap, is its speed less than, greater than, or the same as it was on leaving the tap? Give your reasoning. (2)

1.2.2 Is the volume flow rate (in cubic metres per second) less than, greater than, or the same as it was when the water left the tap? Give your reasoning. (2)

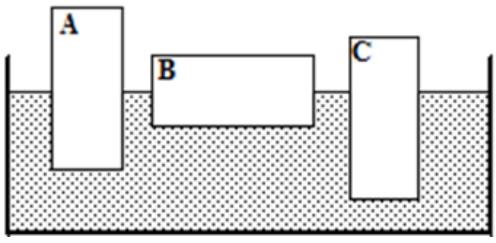
1.2.3 Is the cross-sectional area of the water stream less than, greater than, or the same as it was when the water left the tap? Give your reasoning. (2)

1.2.4 The cross-sectional area of the tap is 1.8×10^{-4} m^2, and the speed of the water is 0.85 $m.s^{-1}$ as it leaves the tap. Ignoring air resistance, find the cross-sectional area of the water stream at a point 0.10 m below the tap. Make sure that your answer is consistent with your answers to questions [1.2.1 -1.2.3]. (5)

1.3

1.3.1 State Archimedes' principle (2)

1.3.2 Three blocks, labeled A, B, and C, are floating in water as shown in the drawing. Blocks A and B have the same mass and volume. Block C has the same volume, but is submerged to a greater depth than the other two blocks. Which one of the following statements concerning this situation is **false**? (2)



A. The density of block A is less than that of block C.
B. The buoyant force acting on block A is equal to that acting on block B.
C. The volume of water displaced by block C is greater than that displaced by block B.
D. The buoyant force acting on block C is greater than that acting on block B.
E. The volume of water displaced by block A is greater than that displaced by block B.

1.4

1.4.1 State Torricelli's theorem (2)

1.4.2 A closed tank containing seawater to a height of 11.0 m also contains air above the water at a **gauge** pressure of 3.00 atm. Water flows out from the bottom through a small hole. Calculate the efflux speed of the water. (6)

1.5 Derive an expression for the terminal speed v_t of a sphere falling in a viscous fluid in terms of the sphere's radius r, density ρ and the fluid viscosity η, assuming that the flow is laminar so that Stokes' Law is valid. (8)

Question 2 – Nuclear Physics [28 marks] **Start on a new page**

2.1

2.1.1 Using the empirical formula for the radius of a nucleus, $r \approx r_o A^{1/3}$, where r_o = 1.2 *fermis*, show that the volume of a nucleus (which is assumed to be spherical) is directly proportional to its nucleon number *A.* (3)

2.1.2 Give a reasonable argument concluding that the mass *M* of a nucleus of nucleon number *A*, is approximately $M \approx m_n A$, where m_n is the mass of a neutron. (2)

2.1.3 Use the results of 2.1.1 and 2.1.2 to prove that the nuclear density is constant for all atoms. (3)

2.1.4 Calculate the density referred to in 2.1.3. Express your answer in $g.cm^{-3}$. (2)

2.2 Calculate the mass defect (in atomic mass units) **and** the binding energy *per* nucleon (in MeV) of the nuclide $^{15}_{6}C$ (atomic mass = 15.007306 u). (5)

2.3 Determine the symbol ${}^{A}_{Z}X$ (and hence the name) for the parent nucleus whose α-decay produces the same daughter as

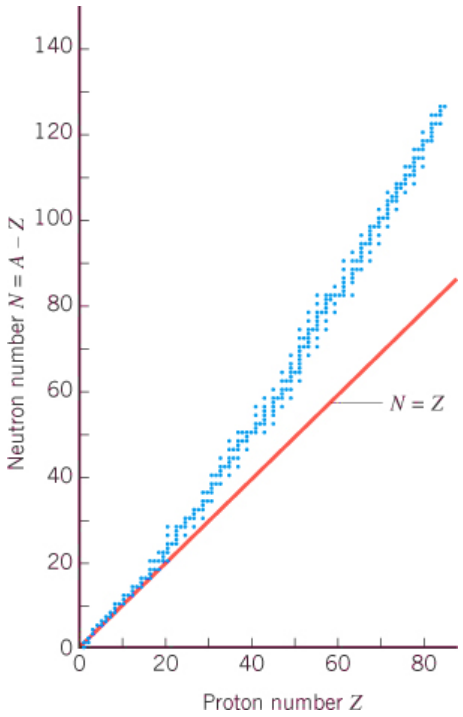
2.3.1 the β^- decay of Thallium (${}^{208}_{81}Tl$).
2.3.2 the β^+ decay of Thallium (${}^{208}_{81}Tl$). (4)

2.4 Initially, two radioactive nuclei *A* and *B* are present in equal numbers. Three days later, there are three times as many *A* nuclei as there are *B* nuclei. The half-life of species *B* is 1.50 days. Find the half life of species *A.* (4)

CHOOSE EITHER 2.5 OR 2.6

2.5 A certain device used in radiation therapy for cancer contains 0.50 g of cobalt ${}^{60}_{27}Co$ (59.933 819 u). The half-life of ${}^{60}_{27}Co$ is 5.27 years. Determine the activity (in Bq) of the radioactive material. (5)

2.6 The graph shown below, summarizes the relationship between the neutron number and the proton number of elements. Using the graph, explain this relationship. (5)

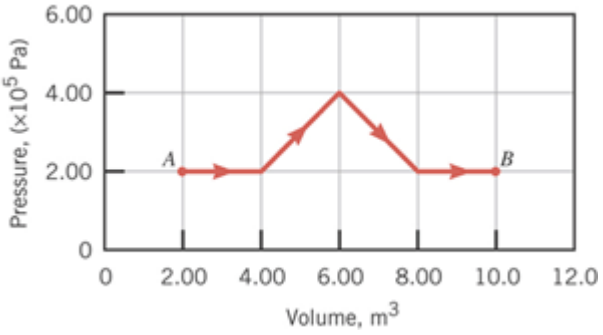


Question 3 - Thermodynamics [35 marks] Start on a new page

3.1 State the following laws

3.1.1 The Zeroth of law of Thermodynamics (2)
3.1.2 The Second law of Thermodynamics (the entropy statement) (2)
3.1.3 The Third law of Thermodynamics (2)

3.2 A monatomic ideal gas expands from point *A* to point *B* along the path shown in the drawing blow;



3.2.1 Determine the work done by the gas. (4)
3.2.2 The temperature of the gas at point A is 185 K. What is its temperature at point B? (3)
3.2.3 How much heat has been added to or removed from the gas during the process? (3)

CHOOSE EITHER 3.3 OR 3.4

3.3 Draw a fully labelled *PV* diagram summarizing the operation of a diesel engine. (5)

3.4 Draw a fully labelled *PV* diagram summarizing the Carnot cycle. (5)

3.5 A quantity of heat is added to two **identical** samples of a monatomic ideal gas. In the first sample the heat is added while the volume of the gas is kept constant, and the heat causes the temperature to rise by 75 K. In the second sample, an identical amount of heat is added while the pressure (but not the volume) of the gas is kept constant. By how much does the temperature of this sample increase? (5)

3.6 A refrigerator is kept in a garage that is not heated in the cold winter or air-conditioned in the hot summer. Does it cost more for this refrigerator to make a kilogram of ice cubes in the winter or in the summer? Give your reasoning. (2)

3.7 Due to a tune-up, the efficiency of an automobile engine increases by 5.0%. For an input heat of 1300 J, how much more work does the engine produce after the tune-up than before? (5)

Question 4 – Heat Transfer [14 marks] **Start on a new page**

4.1 Define or state the following:

4.1.1 Convection, and (2)
4.1.2 Wien's Displacement Law. (2)

4.2 Due to a temperature difference ΔT, heat is conducted through an aluminium plate that is 0.035 m thick. The plate is then replaced by a stainless steel plate that has the same temperature difference and cross-sectional area. How thick should the steel plate be so that the **same** amount of heat per second is conducted through it? (4)
[Thermal conductivities of steel and aluminium are 14 $J.s^{-1}.m^{-1}.(^oC)^{-1}$ and 240 $J.s^{-1}.m^{-1}.(^oC)^{-1}$, respectively]

4.3 A solid sphere has a temperature of 773 K. A chemical engineer melts down the sphere in a furnace and recasts it into a cube that has the **same** emissivity and emits the same radiant power as the sphere. What is the cube's temperature? (6)

Question 5 – AC Theory [28 marks] **Start on a new page**

5.1 A series *RLC* circuit has R = 425 Ω, L = 1.25 H, C = 3.50 μF, ω = 377 s^{-1} and a peak voltage of 150 V. Calculate

5.1.1 The impedance of the circuit. (2)
5.1.2 The peak current in the circuit. (2)
5.1.3 The phase angle between the current and voltage. (2)
5.1.4 The power factor of the circuit. (2)
5.1.5 The peak voltage across the inductor. (2)
5.1.6 The rms voltage **and** rms current. (2)
5.1.7 The average power delivered to the circuit. (2)
5.1.8 Is the circuit resistive, capacitive or inductive? Give reason(s). (1)

5.2 The resonant frequency of a series RCL circuit is 9.3 kHz. The inductance and capacitance of the circuit are each tripled.

5.2.1 What is the new resonant frequency? (3)
5.2.2 Explain what is meant by the term *resonance* in an ac circuit . (1)

5.3 A transformer for home use of a portable radio reduces 240 V to 9.0 V ac. The secondary coil contains 30 turns and the radio draws 400 mA of current. Assuming that this is a 100% efficient transformer, calculate

5.3.1 The number of turns in the primary coil. (2)
5.3.2 The turns ratio. (2)
5.3.3 The current in the primary coil. (2)
5.3.4 The power transformed. (2)
5.3.5 Is this a step-down or a step-up transformer? Give reason(s). (1)

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